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Product formulation and sensory acceptance of three soy concept foods utilizing three different soy derivatives

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PRODUCT FORMULATION AND SENSORY ACCEPTANCE OF THREE SOY CONCEPT FOODS UTILIZING THREE DIFFERENT SOY DERIVATIVES

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The objective of this study was to develop soy concept foods with potential marketability in food industry for health conscious consumers. Fourteen commercial soy protein isolate samples were obtained from various processors. The flavor profiles of soy protein isolates were evaluated by five expert panelists. The three soy protein isolate samples with the most acceptable flavor profiles were utilized for further analysis and development of soy concept foods including cranberry nut soy pudding, two bean soy dip and a soy based meal replacer. Based on consumer acceptability studies, it appears that two bean soy dip may have the most potential for success in food industry. No differences ($P>0.05$) existed in acceptability among soy products in any of the soy concept foods, ISP may have the most potential for utilization in the development of new products since numerical values were slightly higher when this soy protein was incorporated into concept foods.

DEDICATION

I dedicate this manuscript to my ever loving parents, siblings, friends, well wishers, Dr. Coggins, and Dr. Schilling. Thank you all!

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CHAPTER I

INTRODUCTION

Soybean, Glycine max (L) Merr., is the most important cash crop in the United States due to its adaptability and ability to fix nitrogen (Smith and Circle, 1972; Ofosu-Budu, *et* al., 1993). The use of soy protein in soy concept foods could increase soybean utilization in the United States. Soybeans have also been utilized more in the food industry due to increasing popularity of soy based foods which have increased in production over the last decade due to their nutritional benefits and health claims.

Soybeans, which originated in China around 4000-5000 years ago (Liu, 1997), play a vital role in Asian culture, both as a food and as a medicinal agent. However, in the United States and Europe, soybeans have been traditionally known for their high protein content and edible oil (Messina, 1995). Soybeans possess various components such as isoflavones, phytates, fiber, tocopherol, phytosterols, trypsin inhibitor, soy lecithin, and oligosaccharides, which are also known as a powerhouse of phytochemicals and are believed to confer a variety of health benefits (Tripati and Misra, 2005). Soy products did not gain popularity among U.S. consumers until medical studies indicated that the consumption of soy protein could decrease total serum cholesterol and decrease the risk of several cancers (Anderson, *et* al., 1995; Messina, 1997; and Zind, 1998). In response to medical studies, the U.S. Food and Drug Administration (FDA, 1999) approved a health claim for soy products in regards to reducing the risk of coronary heart disease in October, 1999. In order to state this claim, foods must contain 6.25 grams of soy protein per serving, be low in fat (less than 3 grams), have low amounts of saturated fat (less than 1 gram), be low in cholesterol (less than 20 milligrams), have less than 480 milligrams sodium for individual foods, have less than 720 milligrams of sodium if considered a main dish, and have less than 960 milligrams of sodium if considered a meal (Federal Register, 1999). The approval of health claims combined with positive health benefits has greatly increased consumer awareness of soy products and created a large market potential for soy foods (Drake, *et* al., 2001; Ohr, 2000).

Americans are known for adapting many kinds of foreign foods to their own tastes and have developed a new class of soy foods known as "Second Generation" soy foods. These foods are comprised of products such as tofu hot dogs and ice cream, veggie burgers, soymilk yogurt and cheese, soy flour pancake mix and various other prepared Americanized soy foods (Golbitz, 1995).

The novel challenge faced by food technologists is to incorporate soy protein into various new food products while maintaining the acceptability of the products. With changing life styles, customers demand products that can satisfy their evolving needs. In today's market there are an increasing number of products with added value, such as special nutritional benefits and ready-to-eat convenience products. Soy concept foods address these demands. Products such as cranberry nut soy pudding, soy based meal replacer, and two bean soy dip are an innovative mixture of natural products such as sweet potatoes, soy protein isolate, pecans, cranberries, walnuts, corn, fat-free refried beans, corn, black-eyed peas, black pepper, onion powder, garlic powder and other ingredients which make the product unique to today's market place. A possible barricade to the acceptance of these types of products may be the negative perception of soy flavor to many consumers. Wansink (2003) reported that consumers have a negative perception and taste stigma towards soy based products even if soy is not added into the food product.

The purpose of this project was to utilize soy as an incorporated neutraceutical into soy concept food products. This was achieved by developing concept food products formulated with a soy base with added beneficial food ingredients and performing sensory acceptance studies of the soy concept foods. Each product was made with three soy protein isolates to determine which of the three soy protein isolates was most acceptable to consumers.

CHAPTER II

REVIEW OF LITERATURE

History of Soybeans

Soybean is a food crop that originated in China around 4,000-5,000 years ago (Liu, 1997). The soybean was considered one of the five sacred beans along with rice, wheat, barley and millet in China. The word soybean is called *ta-tou* in China, which means “greater bean” (Simoons, 1991). For many centuries, the soybean has played a vital role in Asian culture, both as a food and medicine (Messina, 1995). In the United States and Europe, soybeans are best known for their high protein content and edible oil.

Chinese and other Oriental people use soybeans as one of the most important sources of dietary protein and oil. Compared to other crops, soybeans produce greater amounts of protein per unit area of land. For these reasons, soybeans are called by various names such as Yellow Jewel, Great Treasure, Nature’s Miracle Protein, and Meat of the Field (Liu, 1997). Soybeans contain saponins, phytates, lectins, protease inhibitors, oligosaccharides, and isoflavones (Liener, 1994). The United States is the largest producer of soybeans with 85.48 million metric tons produced in 2004/05, followed by Brazil, Argentina, China and India. The world soybean production for the year 2005 was 228.63 million metric tons (U.S. Department of Agriculture, March 2005). Soy foods have been consumed for the last 1000 years, but in the last 15 years, North

American and European countries have begun to steadily increase their consumption of soy. There are numerous soy foods available in the market. These products are produced by modern processing techniques in large-scale soybean processing plants as well as by traditional Oriental processing. The foods that are processed traditionally are referred to as traditional foods. Traditional soy foods are divided into fermented and non-fermented soy foods. Traditional fermented soy foods are comprised of tempeh, miso, soy sauces, natto, fermented tofu (sufu) and soymilk products (Golbitz, 1995). Traditional non-fermented soy foods consist of fresh green soybeans, whole dry soybeans, soy nuts, soy sprouts, whole-fat soy flour, tofu, okara and yuba (Golbitz, 1995). “Second Generation” soy foods were developed by Americans which consist of products like tofu hot dogs, tofu ice cream, veggie burgers, soymilk yogurt, soymilk cheeses, soy flour pancake mix and various other prepared Americanized soy foods (Golbitz, 1995).

In the Orient, soy foods play a vital role in the human diet. In the United States, the majority of soybeans are crushed into oil and defatted meal. Defatted soy meal is primarily used as animal feed. Only a small amount of defatted soy meal is processed into soy protein products by modern processing technology (Liu, 1997). Its protein and oil contents are higher in quantity and quality when compared to many legumes. Though soybeans contain higher percentages of unsaturated fatty acids, such as linoleic and linolenic acids, it is considered a healthy oil. Soybean oil is a highly unsaturated semi-drying oil. Soybean oil usage in foods was confined for a considerable period because of its unsaturation and high content of linoleic acid, which imparts a flavor stability problem (Kinsella, 1979; McLeod and Ames, 1988).

Soybean Composition

Soybeans are widely known for their variation in color, size, seed shape, physical properties and chemical composition. The soybean pod is comprised of 8% hull, 90% cotyledons and 2% hypocotyls axis (Wolf and Cowan, 1975). Soybeans have a unique chemical composition. On an average dry- matter basis, soybeans contain about 40% protein and 20% oil. The remaining dry matter is composed of approximately 35% carbohydrates and 5% ash. On a wet basis, soybean composition is 35% protein, 17% oil, 31% carbohydrates and 4.4% ash (Liu, 1997). Soybean oil ranges from 5 to 11% in linolenic, 43 to 56% in linoleic, 15 to 33% in oleic, and 11 to 26% in saturated fatty acids (Liu, 1997). Soybeans have the second highest oil content (20%) next to peanuts which are about 48% on a dry-matter basis. When compared to other cereal and legume species, soybeans have the highest protein content (about 40%) on a dry-matter basis (Liu, 1997).

Soy Protein Ingredients

Soy ingredients include soy flour, soy grits, soy protein concentrates, soy protein isolates, textured soy protein, soy brans, soy germs and many others. Soy flour and grits are considered to be one of the least processed soy protein products (Soy Protein Council, 1987). Soy flour is produced by grinding defatted soy flakes with a protein content of about 50% and is widely used as an ingredient in the bakery industry. The proximate composition of defatted soy flour per 100 grams of edible portion consists of 51.5 grams of protein, 15.5 grams of fiber, 7.3 grams of moisture, 6.2 grams of ash, and 1.2 grams of fat. The remaining portion mainly includes insoluble carbohydrates. According to Lang (1999), full-fat soy flour has been in high demand over recent years since novel technology has allowed its usage as the starting material or ingredient in many foods.

Soy protein concentrate (approximately 70 % protein) is traditionally processed by aqueous alcohol extraction of defatted soy flakes. The function of soy protein concentrate in the meat industry is to bind water and emulsify fat. It is also widely used for protein fortification in different types of food products. Soy protein concentrate has improved flavor and functional characteristics as compared to soy flour and grits.

Soy protein isolate is the most refined soy protein product. It is processed from defatted soy flakes by alkaline extraction, followed by precipitation at an acid pH to remove both soluble and insoluble carbohydrates. Soy protein isolate is light in color, bland in flavor and contains about 90% protein. Due to functional properties which include gelation and emulsification, soy protein isolate is used in a wide range of food applications, such as processed meats, meat analogs, soup and sauce bases, nutritional beverages, infant formulas, and dairy replacers.

Functional Foods and Trends

Consumers have become increasingly interested in the health-enhancing role of specific foods or physiologically-active food components, so called functional foods (Hasler, 1998). The term ‘functional food’ was first used in Japan in the 1980's to describe foods fortified with specific ingredients with certain health benefits. Functional foods are defined as food products that benefit health beyond providing nutrients.

According to Drozen *et* al., (1998), functional foods are defined as foods containing significant levels of biologically active components that impart health benefits beyond basic nutrition. Along with the term functional foods, other terms such as 'medical foods', 'nutraceuticals', and 'nutritional foods', and their definitions have also emerged (Hasler, 1996; Sliverglade, 1998).

According to Hirahara (2004), there were several reasons for the evolution of functional foods in Japan. These reasons include: (1) There was noticeable development in food science and research on intestinal bacteria. (2) Increase in the incidence of chronic diseases and long life spans lead to financial difficulties and medical care costs. (3) Awareness of the public regarding health and nutrition. (4) Technology related to microorganisms in food processing. Americans have contended with certain diseases such as coronary heart disease which is the number one cause of death in the United States, followed by cancer, vision problems, obesity, arthritis, high cholesterol, high blood pressure, diabetes, osteoporosis menopause and other afflictions (Sloan, 2005). The three major reasons for the increased interest in functional foods are increased health care costs, recent legislation, and scientific discoveries. According to Van Poppel (1998), the recent growth in functional foods surpassed conventional foods and supplements, which has attracted manufacturers and consumers (Van Poppel, 1998). The important roles of functional foods include mitigation of disease, health promotion, and reduction of health care costs.

Various types of compounds that are present in functional foods may be responsible for the health benefits that are attributed to those functional foods. Eminent nutraceutical ingredients fall into five categories that include phyto chemicals (Pszczola, 1998), probiotics and prebiotics (Brassart and Schiffrin, 1997), polyunsaturated fatty acids and bioactive proteins/peptides.

Soy products are considered functional foods and have many health benefits other than nutrition. Soy ingredients are known for their high level of quality protein and exclusive functional and nutritional properties that make them valuable ingredients in industrial food applications such as bakery, soft drinks, confectionary, dairy, and breakfast cereals.

American Eating Habits

In consideration of eating habits and health, the USDA has presented dietary guidelines for Americans. Dietary guidelines provide information and advice for choosing a nutritious diet, maintaining a healthy weight, achieving adequate exercise, and "keeping foods safe" to avoid food-borne illness. Poor diet and physical inactivity are responsible for the increase in over-weight problems, obesity, cardiovascular disease, hypertension, osteoporosis, diabetes, and certain cancers.

Good nutrition is essential for good health, and the growth and development of children and adolescents. People are advised to consume foods that are high in nutrients and low to moderate in energy and to keep caloric intake under control (Dietary Guidelines of Americans, 2005). The Dietary guidelines of Americans (2005) recommends consuming foods and beverages that are high in nutrients while choosing foods that minimize one's intake of saturated and trans fat, cholesterol, added sugars, salt, and alcohol. Recommendations for weight control are to eat fewer calories while increasing physical activity. Regular physical activity and physical fitness are important for one's health, sense of well-being and maintenance of a healthy body weight. Consumption of fruits and vegetables, whole grains, fat free or low fat milk and milk products are important for good health. Consumption of less than 2300 mg of sodium per day is good for one's health and can prevent the risk of elevated blood pressure. Dietary fiber has a number of beneficial effects and recommended dietary fiber intake is 14 grams per 1,000 calories of consumption.

Health Benefits of Soy Foods

Soybeans are well known for their high protein and oil content, but for the past decade there has been extensive research by clinicians and researchers that have revealed health benefits that are related to the consumption of soy foods (Messina, 1997; Barnes, 1998; Setchell and Cassidy, 1999). There has been much research on the discovery of the role of soy foods in preventing and treating chronic diseases and researchers suggest that consuming soy protein based foods may be beneficial to one's overall health. Soybeans are composed of proteins, carbohydrates, fiber, fats, and a powerful array of phytonutrients with accomplished biopharmaceutical effects (Liu, 1997). Soybeans and soy foods are considered health foods and can be part of a healthy diet due to their high protein content and apparent role in reducing the risk of certain chronic diseases. Soybeans have a higher protein content than other brans and have good nutritional quality when they are processed properly (Liener, 1978). The amino acid profile and the amount of protein in the soybeans are nutritionally beneficial (Messina, 1995). The human body requires twenty amino acids, of which our body produces eleven. The remaining nine amino acids must come from the different foods that we consume and the protein in soybeans provides the remaining nine amino acids. The limiting amino acids in soybeans, methionine and cysteine, are in sufficiently high levels to meet human protein needs when consumed at the recommended level of protein intake (Young, 1991; Messina, 1997).

Soy Intake and Heart Disease

Coronary heart disease is the most common cause of death with approximately 500,000 deaths occurring each year in the United States (American Heart Association, 2005). Many scientific studies conducted over the last several years state that the consumption of soybean and soy foods may reduce the risk of heart disease (Tikkanen and Aldercreutz, 2000). Soy foods are not only low in saturated fat and cholesterol free, but also contain proteins, which have been shown to directly lower blood cholesterol, potentially reducing the risk of heart disease (Erdman, *et* al., 2000). The soy isoflavone genistein may increase the flexibility of blood vessels (Anderson, *et* al., 1995; Messina, 1995). The cholesterol lowering effect of soy protein is promoted as a weapon in the fight against coronary heart disease. According to Anderson, *et* al. (1995), every 1% reduction in cholesterol reduces coronary heart disease risk by approximately 2-3%. In October 1999, the U.S. Food and Drug Administration (FDA, 1999) approved a health claim for soy products. This health claim can be placed on the product label and states that the product reduces the risk of coronary heart disease (Federal Register, 1999). The food manufacturers can claim that, "Diets low in saturated fat and cholesterol that includes 25 grams of soy protein a day may reduce the risk of heart disease. One serving of (name of the food) provides ___ grams of soy protein." To qualify for this claim, foods must contain the following items in each serving: 6.25 grams of soy protein, low fat (less than 3 grams), low saturated fat (less than 1 gram), low cholesterol (less than 20 milligrams), less than 480 milligrams of sodium for individual foods, less than 720 milligrams of sodium if considered a main dish, and less than 960 milligrams of sodium if considered a meal (Federal Register, 1999).

Soy Intake and Cancer Risk

Cancer is, second only to heart disease as a cause of death, in the United States. Messina and Messina (2000) stated that, "Soya foods are rich in anticarcinogens, substances that prevent and control cancer." The potential anticarcinogen in soy are protease inhibitor, phytates, phytosterols, saponins, phenolic acids, and isoflavones (Messina and Erdman, 1995). Soy foods contain isoflavones, which are important in cancer prevention and treatment. A reduced cancer risk diet means eating less fat, more fiber, and more fruits and vegetables. Soy foods meet these dietary guidelines because they are low in saturated fat, high in fiber, and contain many other important nutrients, including essential amino acids. The two primary isoflavones in soy beans are daidzein and genistein. Genistein inhibits the development of cancer cells and tumors, and researchers have reported that isoflavones act as antiestrogen and may reduce the risk of breast cancer and endometerial cancer (Zava and Duwe, 1997). Soybeans and soy foods also help in reducing the risk of several other types of cancers, including lung, colon, rectal, stomach and prostrate cancer.

Soy Intake and Osteoporosis

Osteoporosis is a worldwide health problem and approximately 10 million people in the United States have osteoporosis, of which 8 million are women (National

Osteoporosis Foundation, 2002) and more than 18 million have low bone mass, placing them at an increased risk for osteoporosis (National Osteoporosis Foundation, 2002). In 1990, there were 1.66 million hip fractures worldwide, two-thirds of which were women. Osteoporosis is a disease that weakens bones and results in bone fractures. Researchers suggest that soybean and soy food consumption may reduce the risk of osteoporosis. The isoflavones, which are present in soybeans and soy products, play a vital role in protecting bones. Isoflavones can influence various biological processes that are controlled by estrogen, including bone metabolism (Potter, 1998).

Soy Intake and Menopause

Scientific and clinical studies suggest that soy foods reduce the risk of menopausal symptoms due to the presence of soy isoflavones. Physiological effects that are related to menopause affects the regulation of body temperature, which can result in "night sweats" and "hot flashes" that are related to a decrease in estrogen production in the body during menopause. Lock (1994) reported that Japanese women have fewer menopausal symptoms than American woman. The main reason proposed for lower menopausal symptoms was high consumption of soy foods and estrogenic effects of soy isoflavones (Adlercreutz, *et* al. 1992). Extensive research work is going on from a clinical perspective, concerning whether soy foods can be used as a substitute for hormone replacement therapy. Soy foods may also offer other benefits to women who are going through menopause.

Soy Intake and Diabetes

Soy foods may help reduce diabetes because soy fiber, which is present in soybeans and soy foods, may help regulate glucose levels. A fiber rich diet helps reduce the risk of diabetes. Soybeans and soy foods are rich sources of dietary fiber, and one-quarter cup of soybeans provides eight grams of fiber. In addition to these health benefits, soybeans and soy foods have several other benefits which reduce the risk of kidney disease, obesity, gastrointestinal diseases, and high blood pressure. These health benefits have improved the image of soy foods and increased consumer interest, sales and marketing of soy foods (Liu, 2000).

Functional Soy Ingredients

Isoflavones

Isoflavones are a subclass of flavonoids that are extremely limited in nature, but found in soybeans in considerable amounts. Soybeans contain 2 –5 mgs of isoflavones per gram of protein, and isoflavones are not present in any other food (Wang and Murphy, 1994). Dehulling, flaking, and defatting of soybeans results in the loss of isoflavone content and production of isolated soy protein. Textured soy protein and soy flour contain approximately 5 mgs of isoflavone per gram of protein. The important isoflavones in soybeans are genistein, diadzein, which are sugar containing isoflavone molecules, and glycitein which is present in lower amounts. In various studies, isoflavones have inhibited the growth of cancer cells, lowered cholesterol levels, and inhibited bone resorption (Messina, 1997; Setchell and Cassidy, 1999).

Tocopherol (Vitamin E)

Tocopherol or Vitamin E is a fat soluble vitamin that is a vital antioxidant. Soybeans contain vitamin E in four different isomeric forms, which are alpha-tocopherol, beta-tocopherol, gamma-tocopherol, and delta-tocophereol. In soybeans, alpha-tocopherol, gamma-tocopherol, and delta-tocopherol are present in 10.9 - 28.4, 150 - 191, and 24.6 - 72.5 ug/g amounts, respectively (Guzman and Murphy, 1986). Tocopherol is removed with the oil fraction during the soybean extraction. The US dietary reference intake (DRI) for a 25-year old male for Vitamin E is 15 mg/day. This is approximately 15 International Unit per day. Vitamin E from natural sources is indicated by d-alpha-tocopherol on the ingredient list. The antioxidant property of vitamin E helps prevent degenerative diseases such as heart disease, stroke, senility, diabetes and cancer. It has also been reported that it helps skin retain a youthful appearance.

Phytosterols

Phytosterols are known as plant sterols; however, due to high sitosterol content they are sometimes called sitosterol. Phytosterols are widely found in the plant kingdom, and are chemically similar to cholesterol. Fourty-four phytosterols have been identified in plants, but only three major ones, beta-sitosterol (50%), campesterol (about 33%), and stigmasterol (about 2 - 5%) are found in soybeans. Phytosterols are known to have cholesterol lowering properties (Anderson, *et* al., 1995) and possibly the ability to reduce the risk of cancer.

Phytates

Soybeans and soy foods contain large amounts of phytates (1 - 1.5 % by wt), which are chemically known as inositol hexaphospate. Phytates bind minerals, particularly divalent cations such as iron, zinc, and calcium. Inositol hexaphosphoric acid is commonly known as phytic acid. In soybean, phosphorous is the chief source with 1-1.47 %. Phytates have the potential to help reduce the risk of cardiovascular disease and cancer (Messina, 1997). Presently phyates are plieotropic active, healthful, and act as antioxidants (Shamshuddin, 1999), and are hypoglycemic or hypolipidemic.

Flavor Problems in Soy

Soy protein products are utilized in various processed foods due to their functional properties. The main limiting factor for soybeans use in food products is its flavor (Boatright and Lie, 1999). The flavor of soy protein products is described as having a beany odor and a throat catching and bitter taste (McLeod and Ames, 1988). Consumption of soy foods has received much attention after the approval of soy health claims by the FDA in October 1998 stating that soy proteins reduce the risk of heart disease (FDA, 1998). Due to their high nutritional properties, soy protein isolates are added into various food applications such as nutritional beverages, supplements, nutraceuticals, and nutrition bars, to mention a few. Despite an increase in the use of soy in foods, soy protein use is limited due to its characteristic "beany", grassy, and bitter flavors (Davies *et* al., 1997; Boatright and Crum, 1997). In addition, trans-2, 4-decadienal was found to be a major odor contributor to the oxidized, fatty off-aroma of SPI (Boatright and Lei, 1999). The high proportion of unsaturated fatty acids in soy beans and an abundance of lipoxygenases are the factors that can lead to the development of undesirable flavors in soybean products (Wolf and Cowan, 1975). The oxidation of polyunsaturated fatty acids with soy lipids is catalyzed by lipoxygenases that cause the formation of hydroperoxides. Hydroperoxide degradation, as a subsequent action of lipoxygenase activity, is thought to produce aldehydes (Boatright and Crum, 1997). Aldehydes appear to be the source of beany, grassy off-flavors in soy protein products (Boatright and Crum, 1997).

Driving Force for Soy Expansion

Soy foods are very popular in Eastern Asia but have traditionally not been common foods in European and North American diets. Inspite of its rich history as a food, unique features as a crop, and increasing annual production, it was not widely used in Western countries due to its unfamiliar flavor and taste that is commonly described as beany. The twenty-first century is the turning point of the soy food industry (Liu, 2000), and the U.S soyfoods market is one of the fastest growing categories in the food industry (Golbitz, 2000). Of the $1.75 billion retail sales of soy based foods in the U.S. in 1998, soy sauce, soy-based meat alternatives, soy milk, and tofu represented 45.7, 18.6, 12.4 and 11.8% of these sales, respectively (Goblitz, 2000). The soy food market was valued at over 4 billion dollars in 2005 (Soyatech, 2005) in the retail food category with novel and innovative products meeting the ever changing consumer need for convenience, better taste and functional health benefits (Soyatech, 2005). The total market for soy foods in the U.S grew by 2.1% overall from the previous year although categories such as soymilk, chips, snacks, functional beverages, pasta products, cold cereals, yogurt, and other categories continue to grow at higher rates. (Soyatech, 2005). The driving forces behind the expansion of the soy food industry can be attributed to multiple factors including soybean medical discoveries and health benefits in the soy foods, connection between functional foods and soy, improvement in the regulatory climate, increase in consumer awareness, and technological innovations (Liu, 2000).

Sensory Evaluation

According to the Institute of Food Technologists (1975), sensory evaluation is defined as " a scientific discipline used to evoke, measure, analyze, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing". Today, sensory science is a leading research tool applied to many processes and products. Sensory evaluation measures the intensity and complex sensations that result from interactions between the senses and the foods that have been analyzed (Larmond, 1982; Amerine, *et* al., 1965). To determine the relationship between product characteristics and human perception in sensory evaluation, numerical data is collected for analysis. The primary concerns in sensory evaluation are precision, accuracy, sensitivity, and avoiding false positive results (Coggins and Chamul, 2003).

Sensory evaluation is widely used in new food product development and marketing. Sensory evaluation is used as a practical application in product development by aiding in product matching, improvements, and grading. Research is another area where sensory evaluation is frequently used. Evaluation of a product may be needed to determine the effects that experimental treatments have on the sensory characteristics of the product. Finally, quality control and marketing is another application of sensory testing (Meilgaard, *et* al., 1991).

The main purpose of sensory evaluation in new food product development is to determine whether the food product meets the food industry's expectations through the use of testing and statistical analysis. Sensory evaluation of a new food product is performed to determine the consumer response before the food product is placed in the market. For sensory testing, the panelists are required to make independent judgments. These judgments help food companies determine marketing strategies.

Sensory evaluation is differentiated into subjective or objective testing. Subjective testing involves consumer panelists where as objective testing involves use of laboratory instruments or a trained descriptive panel. Both types of tests are very important and necessary under varying conditions (Meilgaard, *et* al, 1991). One example of subjective testing is the Hedonic Rating Scale. It is used to determine the level of liking for food products by a population. This test relies on people's ability to communicate their perception of like and dislike. Hedonic testing is popular because it may be used with untrained people as well as with trained panelists. A minimum knowledge of verbal ability is necessary for reliable results.

A 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) is most commonly used in this type of testing (Meilgaard, *et* al, 1991). The 9 distinctions on the hedonic scale are (9) like extremely, (8) like very much, (7) like moderately, (6) like slightly, (5) neither like nor dislike, (4) dislike slightly, (3) dislike moderately, (2) dislike very much, and (1) dislike extremely.

Hedonic scale ratings are converted into numerical scores, and statistical analysis is applied to determine differences in degree of liking between or among samples. A hedonic scale rating test can yield both absolute and relative information about the test samples. Absolute information is derived from the degree of liking or disliking indicated for each sample, whereas relative information is derived from the direction and degree of difference between or among the sample scores (IFT, 1981).

Nutritional Analysis

Soybeans have a unique chemical composition. On an average dry-matter basis, soybeans contain about 40% protein and 20% oil. The remaining dry matter is composed of approximately 35% carbohydrates and 5% ash. On a wet basis, soybean composition is 35% protein, 17% oil, 31% carbohydrates and 4.4% ash (Liu, 1997). Soybean is highly nutritious. Its protein and oil contents are high in quantity and quality (Liu, 1997). Because of its high proportion of unsaturated fatty acids, such as linoleic and linolenic acids, it is considered to be healthy oil (Tripati and Misra, 2005).

Soybean is a good source of niacin, riboflavin, iron, potassium, calcium, magnesium, and phosphorous, (Gandhi, 1985), several fat soluble vitamins, and water soluble vitamins including the B- complex (Gupta, 1982). Soybeans contain more protein than beef, more calcium than milk, and more lecithin than egg. Soy protein contains all of the essential amino acids, most of which are present in amounts that closely match the requirements for humans or animals.

CHAPTER III

SCREENING TEST OF SOY SAMPLES

Abstract

Screening was performed on 14 soy protein products to determine their potential for utilization in soy concept foods without imparting a negative flavor perception. A nine-point hedonic scale was utilized for sensory evaluation and five expert panelists evaluated the samples. Results demonstrated that ultrafine soy powder (UFS), total soy protein (TSP), and isolated soy protein (ISP) received the highest ranks in the hedonic test and did not have any negative functional properties. These soy protein isolates all had liking scores of 8.0 which represent “like very much” on the hedonic scale. Based on market potential, it was determined to use these soy samples to formulate cranberry nut soy pudding, two bean soy dip, and a soy based meal replacer.

Introduction

The consumer's demand for functional foods has led to the development of many soy functional foods. The soy food market was valued at over 4 billion dollars in 2005 (Soyatech, 2005) with novel and innovative products meeting the ever changing consumer need for convenience, better taste and functional health benefits (Soyatech, 2005). The driving forces behind the expansion of the soy food industry can be attributed to multiple factors including soybean medical discoveries and health benefits in soy foods, connection between functional foods and soy, improvement in the regulatory climate, increase in consumer awareness, and technological innovations (Liu, 2000).

Soybeans contain isoflavones, phytates, fiber, tocopherol, phytosterols, trypsin inhibitor, soy lecithin, oligosaccharides which are believed to confer a variety of health benefits (Tripati and Misra, 2005). The main objective of this part of the study was to determine the acceptance and preference of soy samples (Table 3.1) that could be used in the formulation of soy concept foods using a 9 point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely).

Table 3.1 Commercial soy sample codes, protein content (%), and manufacturing codes for soy samples that were screened for their usability in soy concept foods.

Soy Sample Code*	Protein (%)	Manufacturer Code*
20501	90	99301
20502	53	99302
20503	90	99302
20504	90	99303
20505	90	99301
20506	100	99301
20507	69	99301
20508	80	99304
20509	70	99304
20510	69	99302
20511	69	99302
20512	69	99302
20513	80	99303
20514	60	99303

* The sample and manufacturer code is kept confidential.

Materials and Methods

Prior to conducting the experiment, 14 commercial soy samples (Table 3.1) were received from various soy product manufacturing plants (Table 3.1). Soy samples were made on a 10% (w/w) solids basis with water. Soy and water were weighed into a beaker (Kimax[R], Kimble, USA) and blended with a hand-held blender (Braun, Type 4169, Mexico) for sixty seconds at low speed to make sure the mixture was thoroughly mixed. Soy mixes were then taken from the beaker and placed in sampling cups (Sweetheart, USA, UR 55, $5^{1/2}$ oz) for evaluation under controlled conditions. Five expert trained panelists from the James E. Garrison Sensory Evaluation Laboratory, Mississippi State University were selected based on their sensory knowledge and time availability. Soy samples were served at ambient temperature (21^{o}C). Panelists were offered a sample of approximately 20 grams of each of the different soy samples. Each panelist evaluated all of the soy samples in one session. To avoid bias and prejudice during the sensory evaluation of different soy samples, panelists were encouraged to take a few sips of water between the tasting of the soy samples. To have consensus on the sensory data, panelists were allowed to discuss the appearance, taste, flavor, texture, and overall of the soy samples.

A 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) was used to rate the liking of the soy samples by the expert panelists. The 9 distinctions on the hedonic scale were (9) like extremely, (8) like very much, (7) like moderately, (6) like slightly, (5) neither like nor dislike, (4) dislike slightly, (3) dislike moderately, (2) dislike very much, and (1) dislike extremely. The overall liking and characteristics of the soy products are listed in Table 3.2.

Results and Discussion

Table 3.2 Flavor characteristics and hedonic liking results provided by expert panelists (n=5) for screening of soy samples for their usability in soy concept foods.

Soy sample code	Protein (%)	Manufacturer Code	Hedonic Liking	Characteristics
20501	90	99301	7.0	beany, watery, less viscosity
20502	53	99302	5.0	too beany, very thin, chalky
20503	90	99302	6.0	beany and thick
20504	90	99303	8.0	slight beany, cleans up well, high foaming
20505	90	99301	7.0	salty, foamy, slight beany flavor
20506	100	99301	7.0	raw bean taste, slight sweet very thin
20507	69	99301	8.0	chalky, slight sweet, bland, slight thickness
20508	80	99304	8.0	slight beany, bland, good taste
20509	90	99304	8.0	toasted, flavor, excellent taste, slight beany
20510	69	99302	7.0	very bland, cereal
20511	69	99302	7.5	very bland, good after-taste
20512	69	99302	7.0	bland, brown colored
20513	80	99303	4.0	beany flavor, paint after taste
20514	90	99303	8.0	bland flavor, slight sweet

The results indicated that ultrafine soy powder (UFS) (Lot # SYPDDA 644225, Soy-N- Ergy, Ann Arbor, MI, 48108), isolated soy protein (ISP) (Lot# ZISPCHH 518250, Soy-N- Ergy, Ann Arbor, MI, 48108), and total soy protein (TSP) (Cargill Health and Food Technologies, Wayzata, MN, 55391) were ranked higher than all other samples except 20504 and 20507. However, these products could not be used in the soy concept foods because of their high foaming capacity and viscosity. The other samples were chosen for their bland flavor profile, low foaming capacity, and low viscosity that would enhance their usability in soy concept foods.

Conclusions

Three soy protein isolates, ultrafine soy powder (UFS), total soy protein (TSP), and isolated soy protein (ISP) were selected for use in the soy concept foods due to their bland flavor and results from sensory testing. The protein levels of these soy derivatives will add the needed protein to foods designed as meal replacers or alternatives. Also, the healthy aspect of soy incorporated into these types of foods is advantageous from a marketing stand point.

CHAPTER IV

PRODUCT DEVELOPMENT OF SOY CONCEPT FOODS

Abstract

Soy concept foods with dessert, snack, and meal replacer profiles, were prepared with three soy protein isolate treatments consisting of ultrafine soy protein (UFS), total soy protein (TSP), and isolated soy protein (ISP). The objective of this part of the research was to utilize soy as an incorporated nutraceutical into soy concept foods and determine which of the three commercial soy samples were the most acceptable to consumers. Based on consumer acceptability studies, it appears that two bean soy dip may have the most potential for success in the food industry. Although, no differences ($P>0.05$) existed in acceptability among soy protein products in any of the soy concept foods, isolated soy protein (ISP) may have the most potential for utilization in the development of new products since numerical values were slightly higher when this soy protein was incorporated into the various soy concept foods.

Introduction

Soybeans, which originated in China 4000-5000 years ago (Liu, 1997), play a vital role in Asian culture, both as a food and as a medicinal agent. In Europe and North America, soybeans have been used for their high protein and edible oil content (Messina, 1995). Ample attention has been given to soy and soy food products during the last three decades due to their high nutritional value and functional properties (Carroll, 1991; Ohr, 1997; Berry, 1998).

In response to medical studies, in October 1999, the U.S. Food and Drug Administration (FDA, 1999) approved a health claim for soy products that allows food labels to state that soy protein reduces the risk of coronary heart disease. In order to state this claim, foods must contain 6.25 gms of soy protein per serving, be low fat (less than 3 grams), be low in saturated fat (less than 1 gm), have low cholesterol (less than 20 milligrams), and have a sodium value of less than 480 mgs for individual foods, less than 720 mgs if considered a main dish, and less than 960 mgs if considered a meal (Federal Register, 1999). The approval of health claims combined with positive health benefits has greatly increased consumer awareness of soy and created a large market potential for soy foods (Drake, *et* al. 2001; Ohr, 2000).

The objective of study was to utilize soy as an incorporated nutraceutical into soy concept food products and determine which soy protein isolate was most acceptable to the consumer.

Materials and Methods

Soy Protein Isolates

Three soy protein isolates, namely total soy protein (TSP) (Cargill Foods, Wayzata, MN, USA), isolated soy protein (ISP) (Soy-n-Ergy, Ann Arbor, MI, USA), and ultrafine soy powder (UFS) (Soy-n-Ergy, Ann Arbor, MI, USA) were used separately for the formulation and preparation of soy concept foods.

Process Description of the Soy Concept Food

Soy concept foods were processed at the Mississippi State University Pilot Plant (Ammerman- Hearnsberger Food Processing Plant). Table 4.3 provides the formulations of the three treatments. The ingredients (Table 4.1) were weighed on an electronic weighing balance (Model #603D, Denver Instruments,TX), mixed in a Steam jacketed kettle with constant stirring and heated to approximately 38^{o}C to aid in both the mixing and dissolving of the soy protein isolate. Each formulation was then pasteurized at 74^{o}C for thirty min. After pasteurization, the soy product was quickly cooled to 4.4^{o}C and allowed to set for flavor enhancement. The product was then placed in a cold store room (35^{o}F/ 2.1^{o}C) for 12 hours for firming, settling, and crystallization to the proper consistency prior to consumer testing. Two more duplicates of each soy concept food were prepared with two other soy protein isolates.

Table 4.1 Ingredient list for soy concept foods that were formulated with three different soy protein isolates.

Ingredients	**Name of the supplier, city, state, country**
Water*†Δ	Georgia Mountain Water Inc., (Blue Ridge, USA)
Skim Milk*†Δ	Barber's Dairy, (Birmingham, AL, USA)
Sweet Potato Mash*Δ	Allen Canning Co.,(Siloam Springs, AR, USA)
Non-fat Dry Milk*†Δ	Kroger Co., (Cincinnati, OH, USA)
Egg Yolk Solids*†Δ	Tranin, Inc. (Jackson, MS)
Stabilizer*†Δ	Continental Custom Ingredients Inc., (IL, USA)
Chargrill Flavor*†Δ	Kraft Food Ingredients
Butter Flavor*†Δ	Butter Buds Food Ingredients (Racine, WI, USA)
Salt*†Δ	Southern Home (Birmingham, AL, USA)
Sucralose Powder*	McNeil Nutritionals (McIntosh, AL, USA)
Citric Acid*†Δ	Archer Daniels Midland (Decatur, IL,USA)
Caramel*	Givaudan (Cincinnati, OH, USA)
Soy protein isolate 1*†Δ	Cargill Foods (Wayzata, MN, USA)
Soy protein isolate 2*†Δ	Soy-n-Ergy (Ann Arbor, MI, USA)
Soy protein isolate 3*†Δ	Soy-n-Ergy (Ann Arbor, MI, USA)
Walnuts* (chopped to 0.64 cm)	Kroger Co., (Cincinnati, OH, USA)
Pecans* (chopped to 0.64 cm)	Kroger Co., (Cincinnati, OH, USA)
Cranberry* (whole dried)	Sun-Maid (Kingsburg, CA, USA)
Non fat refried beans †	Kroger Co., (Cincinnati, OH, USA)
Leaf Oregano †Δ	Kroger Co., (Cincinnati, OH, USA)
Garlic Powder †Δ	Kroger Co., (Cincinnati, OH, USA)
Onion Powder †Δ	Kroger Co., (Cincinnati, OH, USA)
Canned Black eyed peas Δ	Kroger Co., (Cincinnati, OH, USA)
Ham flavored soy bits Δ	McCormick Inc., (Hunts Valley, MD, USA)

***** - Ingredients used in the preparation of a cranberry nut soy pudding.
†- Ingredients used in the preparation of a two bean soy dip.
Δ- Ingredients used in the preparation of a soy based meal replacer.

Table 4.2 Ingredients that were not acceptable to expert panelists in the formulation of cranberry nut soy pudding.

Ingredients	Manufacturer	Ingredient Description
Dried Apples (Chopped ¼ ")	Sun-Maid Growers of California, Kingsburg, CA, USA	Expert panelists rejected the dried apples in the inclusion of pudding due to a sulfur smell and slightly sour, metallic, and astringent flavors.
Sliced Apples (Chopped ¼ ")	Mariani Packaging Company Inc., Vacaville, CA, USA	The flavor was sour, metallic, and astringent. Expert panelists did not accept sliced apples in soy pudding.
Raisins (Chopped ¼ ")	Sun-Maid Growers of California, Kingsburg, CA, USA	Raisins reduced the sweetness and color homogeneity and increased the stickiness and chewiness of the product.
Sun Dried Apricots (Chopped ¼ ")	Sun-Maid Growers Inc., Yuba city, CA, USA	Sun dried apricots were acidic, astringent and unacceptable when mixed with soy pudding.

Table 4.3 Ingredients that were not acceptable to expert panelists in the formulation of two bean soy dip.

Ingredients	Manufacturer	Ingredient Description
Ground Coriander	Inter-American Products, Inc., OH, USA	The flavor was described as spicy, aromatic, and pungent when mixed with two bean soy dip. Addition of coriander was not acceptable to the expert panelists.
Ground Ginger	Burns Philip Food Inc., San Francisco, CA, USA	Addition of ground ginger into two bean soy dip was not liked by the expert panelists due to strong flavor characteristics such as lemon odor. It also had a strong, aromatic, and pungent aftertaste.

Table 4.4 Ingredients that were not acceptable to expert panelists in the formulation of soy based meal replacer.

Ingredients	Manufacturer	Ingredient Description
Cayenne Pepper	Zatarain's New Orleans, LA, USA	The panelists observed a bitter, raw taste. The pepper was also pungent and very hot when mixed with the soy based meal replacer. This resulted in the rejection of using cayenne pepper in the soy based meal replacer.
Ground Nutmeg	Inter-American Products, Inc., OH, USA	Expert panelists observed bitter, citrus, musty, and woody flavors when nutmeg was mixed with soy based meal replacer. These flavors resulted in the rejection of using nutmeg in the soy based meal replacer.

Sample Preparation of Cranberry Nut Soy Pudding

The soy product was prepared and kept in the cold storage refrigerator (Viking Professional, 18.5 Cu. ft, USA) over night for 12 h at 2.1°C. The product was then removed from the cold storage refrigerator and transferred into an 8.5" porcelain bowl (Home Trends $_{TM,}$ China). The ingredients were weighed on an electric weighing balance (Model # 603D, Denver Instruments, TX) according to the designated formulation. The ingredients were measured and placed in a 2qt porcelain bowl (Home Trends $_{TM,}$ China). The measured ingredients such as pecans (5.5%), walnuts (0.9%) and cranberries (7.2%) were mixed into the prepared soy product. The soy product was constantly stirred with a balloon whisk/beater (Oneida 18/8 Stainless, USA) for proper mixing of ingredients. Prior to consumer acceptability, the processed product was well mixed with pecans, walnuts, and cranberry and served in cups with approximately 50 grams (Sweetheart, USA, UR 55, $5^{1/2}$ oz) at 5°C for consumer acceptability testing. The consumers were provided with water (Georgia Mountain Water Inc., USA), an expectoration cup (Dart Co., USA), a No.2 pencil (Dixon Co., USA), disposable spoon (Reliable Spoons Co., USA), unsalted crackers (Premium, Nabisco Co., USA), and a score sheet on a plastic serving tray (Prolon Co., USA) with dimensions (10"X15").

Sample Preparation of Two Bean Soy Dip

The prepared soy product was removed from the cold storage refrigerator (Viking Professional, 18.5 Cu. ft, USA) which was stored at 2.1°C for 12 hours. The product was transferred into an 8.5" porcelain bowl (Home Trends $_{TM,}$ China) and heated to 55°C.

Onion powder (1.0%), leaf oregano (0.1%), garlic powder (0.8%), and ground red pepper (0.5%) were weighed on an electric weighing balance (Model # 603D, Denver Instruments, TX) according to the designated formulation. Once, the product was heated to 55^{o}C onion powder, leaf oregano, garlic powder and ground pepper are mixed into the soy with a balloon whisk/beater (Oneida 18/8 Stainless, USA). Approximately 50 grams of the product (Sweetheart, USA, UR 55, $5^{1/2}$ oz) was served to the consumer at 10^{o}C with bland chips for consumer acceptability testing. The consumers were provided with water (Georgia Mountain Water Inc., USA), an expectoration cup (Dart Co., USA), a No.2 pencil (Dixon Co., USA), a disposable spoon (Reliable Spoons Co., USA), unsalted crackers (Premium, Nabisco Co., USA) and a score sheet on a plastic serving tray (Prolon Co., USA) with dimensions (10"X15").

Sample Preparation of Soy Based Meal Replacer

The soy product was placed in cold storage (Viking Professional, 18.5 Cu. ft, USA) for 12 hours at 2.1^{o}C. The product was transferred into an 8.5" porcelain bowl (Home Trends $_{TM,}$ China). Ham flavored soy bits (3.87%), black-eyed peas (9.3%), corn (11.6%), garlic powder (0.2%), and onion powder (0.23%) were weighed on an electric weighing balance (Model # 603D, Denver Instruments, TX). The soy product was heated to 55^{o}C. When the product reached 55^{o}C, all ingredients were mixed into the soy with a balloon whisk/beater (Oneida 18/8 Stainless, USA). Approximately 50 grams of product (Sweetheart, USA, UR 55, $5^{1/2}$ oz) was served to the consumer. The consumers were provided with water (Georgia Mountain Water Inc., USA), an expectoration cup (Dart

Co., USA), a No.2 pencil (Dixon Co., USA), a disposable spoon (Reliable Spoons Co., USA), unsalted crackers (Premium, Nabisco Co., USA) and a score sheet on a plastic serving tray (Prolon Co., USA) with dimensions (10"X15").

Product Development of a Soy Concept Food Using Trial and Error Method

The experimental design consisted of varying soy protein isolate from 13% to 6.5% in different formulations from formulation #1 to formulation #10 while keeping non-fat dry milk, egg yolk solids, stabilizer, chargrill flavor, butter flavor, salt, sucralose powder, citric acid, walnuts, pecans, and caramel constant and decreasing and increasing levels of water, skim milk, sweet potato mash, soy protein isolate, and cranberry. Prior to conducting the experiment on the formulation design and product development, all the ingredients were received and immediately taken to their proper designated storage areas. The ingredients were weighed on an electric weighing balance (Model #603D, Denver Instruments, TX) according to the random formulation designed. Formulation #10 consisted of 35.6 % sweet potato mash, 13% soy protein isolate, 10% skim milk, 19% water, 4.3% non-fat dry milk, 0.9% egg yolk solids, 0.15% stabilizer, 0.05% chargrill flavor, 0.04% butter flavor, 0.02% salt, 0.01% citric acid, 0.9% walnuts, 10% cranberry, 5.5 % pecans, and 0.01% caramel. The ingredients were mixed in a 500 ml glass beaker and mixed with a magnetic stirrer and heated constantly with stirring for approximately 38^{o}C to aid in mixing and dissolving of the soy protein isolate. The formulation was then pasteurized at 74^{o}C for 30 minutes. After pasteurization, the product was cooled to 4.4^{o}C. Once the product was cooled in the cold store refrigerator (Viking Professional, 18.5 Cu.

ft, USA), cranberry, pecans, and walnuts were mixed in according to the formulation. An informal sensory panel was conducted by the expert panelists for cranberry nut soy pudding. The results demonstrated that the formulation was not acceptable because of the high content of soy protein isolate. Due to the pungent beany flavor, formulation #10 was rejected. So, by the trial-and-error method, the amount of soy protein isolate was decreased from 13% to 12.5%. Besides this, other ingredients were also adjusted. Water level was decreased from 19% to 18.5%, sweet potato mash was decreased from 35.6% to 32.6%, and skim milk was increased from 10% to 14.5%. This was done by keeping all of the other ingredients constant and resulted in formulation #9. After designing the formulation, the product was prepared using the same parameters that were previously used for formulation #10. After preparation of the product, an informal sensory panel was conducted by the expert panelists for product testing. Formulation #9 was also not acceptable to the expert panelists because of the beany flavor and chalky texture observed. The amount of soy protein isolate was then decreased from 12.5% to 12.0%, water was decreased from 18.5% to 18%, skim milk was decreased from 14.5% to 14.0% and sweet potato mash was increased from 32.6% to 34.6% while keeping all other ingredients constant, resulting in formulation #8. The preparation parameters were the same as that of the other formulations. An informal sensory panel was conducted, resulting in the rejection of Formulation #8. The same procedure was followed until the formulation was acceptable. Formulation #1 was accepted by the expert trained panelists in the informal sensory panel. Formulation #1 consisted of the following ingredient percentages: 13.5 % water, 22.45% skim milk, 38.7% sweet potato mash, 6.5% soy protein isolate, 4.3% non-fat dry milk, 0.9% egg yolk solids, 0.15% stabilizer, 0.05% chargril flavor, 0.04% butter flavor, 0.02% salt, 0.01% citric acid, 0.9% walnuts, 7.2% cranberry, 5.4 % pecans, 0.01% caramel. The preparation parameters were the same as those that were used for the other formulations.

The same procedure and process was used for the product development and formulation design of two bean soy dip and soy based meal replacer. The acceptable levels of soy protein isolate in cranberry nut soy pudding, two bean soy dip, and soy based meal replacer were 6.5%, 7.5%, and 6.5% respectively. The trial-and-error method formulations are listed in tables 4.14, 4.15, and 4.16 respectively.

Nutritional Analysis

Nutritional Analysis of each soy concept food treatment was determined according to methods by the Association of Official Analytical Chemists (AOAC, 1995). Protein content, fat content, total fiber, sodium and carbohydrates were performed by Hand Chemical Laboratory, at Mississippi State University. Protein content was measured using Kjeldahl analysis using a protein factor of 6.25 according to AOAC method 991.20.1. Fat content was determined using (Soxtech method) AOAC method 933.05. Fiber content was determined using the methods as outlined in AOAC methods 991.43 and 985.29. Carbohydrate percentage was calculated as the difference of the sum of the percentages of protein, fat, ash content and moisture content from 100. A Bomb calorimeter was used to measure the total energy of the food product.

Hunter Color Measurement

Color analysis was performed using the Hunter Labscan Model 6000 0/74 ° Colorimeter and Universal software v. 1.4 (Hunter Associates Laboratories, Inc., Reston, VA). The machine was calibrated with standard black and white color plates, and set at a port diameter of 2.54 cm. Color Measurements (L*, a*, and b*) were obtained for each treatment. Hunter color: L (0 = black, 100 = white), a (+a = red, -a = green), b (+b = yellow, -b = blue). Each treatment within each replication was measured in triplicate and means were obtained.

Consumer Analysis

Consumer analysis was conducted in the James E. Garrison Sensory Evaluation Laboratory, Department of Food Science, Nutrition, and Health Promotion, at Mississippi State University, Mississippi State, MS. Consumer acceptance tests were conducted by recruiting people from Mississippi State University by email, word-of-mouth, and flyers. Before recruiting consumers, they were asked if they had any food allergies and if they were willing to taste the product. Consumers (n = 150) evaluated cranberry nut soy pudding, two bean soy dip, and the soy based meal replacer in individual booths illuminated with white lighting. The samples were assigned random numbers. The panelists were provided product samples with approximately 50 grams in each cup (Sweetheart, USA, UR 55, $5^{1/2}$ oz). Panelists were provided water (Georgia Mountain Water Inc.), an expectoration cup 5oz (Dart Co., USA), a No.2 pencil (Dixon Co., USA), unsalted crackers (Premium, Nabisco Co., USA) and a score sheet. Each panelist evaluated cranberry nut soy pudding, two bean soy dip, and soy based meal replacer that was formulated with 3 different soy proteins in each session. Consumers evaluated the soy products using a hedonic scale that ranged from 1 "Dislike extremely" to 9 "Like extremely" (Meilgaard *et* al., 1991). Each consumer evaluated the samples based on the liking of appearance, texture, and flavor as well as overall- liking. Consumers signed consent forms consistent with Mississippi State University Human Subjects research approval.

<u>**Statistical Analysis**</u>

A randomized complete block design with three replications was utilized to determine the differences among the color and consumer attributes ($P<0.05$) for the different soy samples within each concept food. The Least Significance Difference (LSD) test was utilized to separate treatment means when differences ($P<0.05$) occurred.

Results and Discussion

Consumers detected no differences ($P>0.05$) in appearance, texture, flavor, and overall liking among the soy protein isolate treatments that were used to formulate cranberry nut soy pudding (Table 4.2). In addition, no differences ($P>0.05$) were observed among replications for appearance, texture, flavor or overall liking. In previous research done by Chen *et* al., (2003), sensory attributes of soy cookies such as flavor, overall liking, and appearance were different for four soy protein concentrates and isoaltes that included TSP (INSTSOY), TSP (Insta-Pro), Concentrate, and Isolate. However, no differences were observed in texture of the product treatments (Chen *et* al., 2003). Although not statistically significant(P>0.05) in the current study, ISP had the highest numerical value for appearance, texture, flavor, and overall liking, and UFS had the lowest numerical value for all attributes (Table 4.2). The mean value for all product treatments were between "neither like nor dislike" and "like slightly" for all three soy protein isolates. Since numerical values were slightly higher for the products formulated with ISP, it may have the most potential for utilization in the development of new soy products.

No differences (P>0.05) occurred in the appearance, texture, flavor, and overall liking of two bean soy dip (Table 4.3) and the soy based meal replacer (Table 4.4) Drake *et* al., (2000) reported a decrease in sweetness perception as soy protein percentage increased in soy yogurt. Walters (1996) reported that soy flavor decreased as sweetness increased, but that soy flavor increased with soy protein addition. Sugars can also have a masking effect on other basic tastes such as bitter and sour (Walters, 1996). Even though results were not statistically significant (P>0.05), ISP had the highest numerical mean value for the sensory attributes when compared to the two other soy protein isolates, TSP and UFS. The mean values for all the product treatments were between "like slightly" and "like moderately" for two bean soy dip and "neither like nor dislike" and "dislike slightly" for the soy based meal replacer. ISP may have the most potential for utilization in the development of the soy products since products formulated with this soy protein were numerically higher in consumer acceptability scores when compared to the other two soy protein isolates.

Two bean soy dip may have the most potential as a new product in the soy food industry. Although, the three products were not compared statistically, the average consumer attributes values are numerically greater than the other two products.

No differences ($P>0.05$) were observed among L^* values for the three soy protein isolates for cranberry nut soy pudding (Table 4.8). Lee *et* al., (1990) reported decreased Lightness (L^*) in yogurts made with soy when compared to dairy yogurts. Although not statistically significant ($P>0.05$), ISP had the lowest numerical value and UFS had the highest numerical value for the three soy protein isolates in respect to L* value. This reveals that soy may cause changes in lightness that may be undesirable in some products but that was not seen in the current study since different concentrations of soy were not evaluated for L*, a*, and b*. No differences ($P>0.05$) were observed in a^* among the three soy protein isolates. Although not statistically significant ($P>0.05$) (Table 4.8), ISP had the highest numerical value and TSP had the lowest numerical value for the three soy protein isolates. No differences ($P>0.05$), were observed among the values of b^* in the three soy protein isolates (Table 4.8). Although not statistically significant ($P>0.05$), TSP had the lowest numerical value and ISP had the highest numerical value for the three soy protein isolates. Color analysis differences of the two bean soy dip and soy based meal replacer among the three replications were observed by instrumental analysis (Table 4.9 and 4.10). No differences ($P>0.05$), were observed among the values of L*, a*, and b* in the three soy protein isolates. Although not statistically significant, TSP had the lowest numerical value and UFS had the highest numerical value for the three soy protein isolates. Since color and consumer acceptability differences do not exist ($P>0.05$), it was evident that any of the soy proteins could be used in the formulation of these products. It is also evident that two bean soy dip and ISP may have the most promise in the product development since they were numerically higher than other treatments in regards to sensory acceptability measurements.

Table 4.5 Mean hedonic scores for consumer acceptability (n=150) of cranberry nut soy pudding in the product development of a soy concept food.

Treatment	Appearance	Texture	Flavor	Overall Liking
ISP	5.8[a]	6.0[a]	5.9[a]	5.8[a]
TSP	5.4[a]	5.8[a]	5.7[a]	5.6[a]
UFS	5.1[a]	5.3[a]	5.7[a]	5.6[a]

[a] Means in columns with same letter are not significantly different (P>0.05).
ISP- Isolated soy protein.
TSP-Total soy protein.
UFS-Ultrafine soy powder.

Table 4.6 Mean hedonic scores for consumer acceptability (n=150) of two bean soy dip in the product development of a soy concept food.

Treatment	Appearance	Texture	Flavor	Overall Liking
ISP	6.1[a]	6.1[a]	6.2[a]	6.2[a]
TSP	5.9[a]	6.0[a]	5.9[a]	5.9[a]
UFS	5.7[a]	6.0[a]	5.7[a]	5.8[a]

[a] Means in columns with same letter are not significantly different (P>0.05).
ISP- Isolated soy protein.
TSP-Total soy protein.
UFS-Ultrafine soy powder.

Table 4.7 Mean hedonic scores for consumer acceptability (n=150) of a soy based meal replacer in the product development of a soy concept food.

Treatment	Appearance	Texture	Flavor	Overall Liking
ISP	5.0[a]	5.3[a]	5.2[a]	5.0[a]
TSP	4.8[a]	5.1[a]	4.9[a]	4.9[a]
UFS	4.5[a]	4.9[a]	4.8[a]	4.7[a]

[a] Means in columns with same letter are not significantly different (P>0.05).
ISP- Isolated soy protein.
TSP-Total soy protein.
UFS-Ultrafine soy powder.

Table 4.8 Mean scores for color analysis (L^*, a^*, b^*) of cranberry nut soy pudding for soy protein isolates in the product development of a soy concept food.

Treatment	L^*	a^*	b^*
ISP	42.1[a]	6.1[a]	18.7[a]
TSP	42.2[a]	5.0[a]	17.7[a]
UFS	42.8[a]	5.9[a]	18.6[a]

[a] Means in columns with same letter are not significantly different (P>0.05).
ISP- Isolated soy protein.
TSP-Total soy protein.
UFS-Ultrafine soy powder.
*Hunter color: L (0 = black, 100 = white), a (+a = red, -a = green), b (+b = yellow, -b = blue).

Table 4.9 Mean scores for color analysis (L^*, a^*, b^*) of two bean soy dip for soy protein isolates in the product development of a soy concept food.

Treatment	L^*	a^*	b^*
ISP	37.8[a]	6.6[a]	11.6[a]
TSP	37.1[a]	7.5[a]	11.0[a]
UFS	39.0[a]	7.3[a]	12.9[b]

[ab] Means in columns with same letter are not significantly different (P>0.05).
ISP- Isolated soy protein.
TSP-Total soy protein.
UFS-Ultrafine soy powder.
*Hunter color: L (0 = black, 100 = white), a (+a = red, -a = green), b (+b = yellow, -b = blue).

Table 4.10 Mean scores for color analysis (L^*, a^*, b^*) of soy based meal replacer for soy protein isolates in the product development of a soy concept food.

Treatment	L^*	a^*	b^*
ISP	43.6[a]	5.9[a]	17.8[a]
TSP	42.3[a]	6.1[a]	18.1[a]
UFS	43.1[a]	5.7[a]	17.9[a]

[a] Means in columns with same letter are not significantly different (P>0.05).
ISP- Isolated soy protein.
TSP-Total soy protein.
UFS-Ultrafine soy powder.
*Hunter color: L (0 = black, 100 = white), a (+a = red, -a = green), b (+b = yellow, -b = blue).

Table 4.11 Nutritional analysis of cranberry nut soy pudding.

Energy	290 calories/ 260 g
Carbohydrate	22 g
Protein	13 g
Fat	11 g
Sodium	250(mg)
Dietary Fiber	10 g

Table 4.12 Nutritional analysis of two bean soy dip.

Energy	35 calories/2 Tbs
Carbohydrate	4 g
Protein	4 g
Fat	0 g
Sodium	90(mg)
Dietary Fiber	<1g

Table 4.13 Nutritional analysis of a soy based meal replacer.

Energy	230 calories/ 340 g
Carbohydrate	34 g
Protein	29 g
Fat	4 g
Sodium	550(mg)
Dietary Fiber	8 g

Table 4.14 Trial and error method formulations for cranberry nut soy pudding.[1]

FORMULA #	WATER	SKIM MILK	SWEET POTATO MASH	SOY PROTEIN ISOLATE	NON-FAT DRY MILK	EGG YOLK SOILDS	STABILIZER	CHARGRILL FLAVOR	BUTTER FLAVOR	SALT	SUCRALOSE POWDER	CITRIC ACID	WALNUTS	CRANBERRY	PECANS	CARAMEL	RESULT [2] (accepted/rejected)
1	**13.5**	**22.45**	**38.6**	**6.5**	**4.3**	**0.9**	**0.15**	**0.05**	**0.04**	**0.02**	**0.02**	**0.01**	**0.9**	**7.2**	**5.5**	**0.01**	**AF**
2	15.0	17.6	40.6	7.5	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	7.4	5.5	0.01	RF
3	15.5	14.0	42.6	8.5	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	7.6	5.5	0.01	RF
4	16.0	10.2	44.6	9.5	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	7.8	5.5	0.01	RF
5	16.5	12.5	40.6	10.5	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	8.0	5.5	0.01	RF
6	17.0	10.0	41.6	11.0	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	8.5	5.5	0.01	RF
7	17.5	13.5	36.6	11.5	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	9.0	5.5	0.01	RF
8	18.0	14.0	34.6	12.0	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	9.5	5.5	0.01	RF
9	18.5	14.5	32.6	12.5	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	10.0	5.5	0.01	RF
10	19.0	10.5	35.6	13.0	4.3	0.9	0.15	0.05	0.04	0.02	0.02	0.01	0.9	10.0	5.5	0.01	RF

[1] All numerical values are percentages of formula.

[2] AF = Accepted Formula , RF = Rejected Formula.

Table 4.15 Trial and error method formulations for two bean soy dip.[1]

FORMULA #	WATER	SKIM MILK	NON FAT REFRIED BEANS	SOY PROTEIN ISOLATE	NON-FAT DRY MILK	EGG YOLK SOILDS	STABILIZER	CHARGRILL FLAVOR	BUTTER FLAVOR	SALT	GROUND PEPPER RED	CITRIC ACID	LEAF OREGANO	GARLIC POWDER	ONION POWDER	RESULT [2] (accepted/rejected)
1	**15.2**	**23.3**	**45.5**	**7.5**	**4.8**	**1.01**	**0.19**	**0.06**	**0.04**	**0.02**	**0.5**	**0.01**	**0.1**	**0.8**	**1.0**	**AF**
2	18.5	18.3	46.5	8.0	5.5	1.01	0.19	0.06	0.04	0.02	0.7	0.01	0.7	0.1	0.4	RF
3	18.0	17.5	46.0	8.5	6.5	1.01	0.19	0.06	0.04	0.02	0.6	0.01	0.6	0.6	0.5	RF
4	17.5	17.5	45.5	9.0	7.0	1.01	0.19	0.06	0.04	0.02	0.5	0.01	0.5	0.5	0.6	RF
5	17.0	17.8	45.0	9.5	7.5	1.01	0.19	0.06	0.04	0.02	0.4	0.01	0.4	0.4	0.7	RF
6	16.5	18.0	44.5	10.0	8.0	1.01	0.19	0.06	0.04	0.02	0.3	0.01	0.3	0.3	0.8	RF
7	16.0	18.2	44.0	10.5	8.5	1.01	0.19	0.06	0.04	0.02	0.2	0.01	0.2	0.2	0.9	RF
8	17.0	17.5	44	11	7.5	1.01	0.19	0.06	0.04	0.02	0.4	0.01	0.3	0.3	0.7	RF
9	16.5	17.5	43.5	11.5	8.0	1.01	0.19	0.06	0.04	0.02	0.3	0.01	0.3	0.3	0.8	RF
10	16.0	18.0	43.0	12.0	8.0	1.01	0.19	0.06	0.04	0.02	0.2	0.01	0.3	0.3	0.9	RF

[1] All numerical values are percentages of formula.

[2] AF = Accepted Formula , RF = Rejected Formula.

Table 4.16 Trial and error method formulations for soy based meal replacer.[1]

FORMULA #	WATER	SKIM MILK	SWEET POTATO MASH	SOY PROTEIN ISOLATE	NON-FAT DRY MILK	LIQUID SMOKE	STABILIZER	CHARGRILL FLAVOR	BUTTER FLAVOR	SALT	HAM FLAVORED SOY BITS	CITRIC ACID	CORN	BLACK EYED PEAS	GARLIC POWDER	ONION POWDER	RESULT [2] (accepted/rejected)
1	**11.61**	**19.35**	**33.1**	**6.5**	**3.68**	**0.23**	**0.14**	**0.05**	**0.03**	**0.02**	**3.87**	**0.01**	**11.6**	**9.3**	**0.2**	**0.23**	**AF**
2	12.0	14.74	36.0	7.0	3.68	0.23	0.14	0.05	0.03	0.02	4.0	0.01	12.0	9.5	0.3	0.30	RF
3	12.5	14.54	35.0	7.5	3.68	0.23	0.14	0.05	0.03	0.02	4.5	0.01	11.0	10.0	0.4	0.40	RF
4	13.5	13.84	34.5	8.0	3.68	0.23	0.14	0.05	0.03	0.02	5.0	0.01	10.0	10.0	0.5	0.50	RF
5	13.0	13.64	34.0	8.5	3.68	0.23	0.14	0.05	0.03	0.02	5.5	0.01	9.5	10.5	0.6	0.60	RF
6	11.0	14.94	33.0	9.0	3.68	0.23	0.14	0.05	0.03	0.02	6.0	0.01	9.5	11.0	0.7	0.70	RF
7	10.5	14.74	32.0	9.5	3.68	0.23	0.14	0.05	0.03	0.02	6.5	0.01	10.0	11.0	0.8	0.80	RF
8	9.0	16.84	30.0	10.0	3.68	0.23	0.14	0.05	0.03	0.02	8.0	0.01	12.0	8.0	1.0	1.0	RF
9	9.5	14.84	31.0	10.5	3.68	0.23	0.14	0.05	0.03	0.02	7.5	0.01	11.5	9.0	1.0	1.0	RF
10	10.0	12.54	31.5	11.0	3.68	0.23	0.14	0.05	0.03	0.02	7.0	0.01	12.0	10.0	0.9	0.90	RF

[1] All numerical values are percentages of formula.

[2] AF = Accepted Formula , RF = Rejected Formula.

CHAPTER V

SUMMARY, IMPLICATIONS, AND CONCLUSIONS

Consumers detected no differences in appearance, texture, flavor, and overall liking among the soy protein isolate treatments that were used to formulate soy concept foods. In addition, no differences were observed among replications for appearance, texture, flavor or overall liking. Although not statistically significant, isolated soy protein (ISP) had the highest numerical value for appearance, texture, flavor, and overall liking, and ultrafine soy powder (UFS) had the lowest numerical value for all attributes in all the three soy concept foods. Out of the three products formulated, two bean soy dip may have the higher potential for success in the soy food industry. The dip had the highest acceptance from the consumer study of the three products tested. Mexican style bean dips are widely known and accepted by the public. Adding a healthful protein source to what is often thought of as a fun food could enhance the appeal of this product. The formulation and seasoning could be optimized to enable the dip to carry a soy heart healthy label, attracting the health conscious consumer as well as the snack food lover. It can also be surmised that these foods, i.e. soy based meal replacer and cranberry nut soy pudding may be “before their time”. An example of this would be yogurt. Introduction of yogurt to the American market was not initially met with overall consumer acceptance. However, 40 years later, yogurt is now seen as a staple in American refrigerators, also the consumption of yogurt is seen as beneficial. In time, soy will probably experience this same market acceptance and consumers will learn to accept its flavor.

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APPENDIX

SCORE SHEET (A), SCORE SHEET (B),

AND CONSENT FORMS

SCORE SHEET (A)

Sensory Evaluation of Soy samples

Date: _____________ **Panelist Code: ___________**

Caution: Samples contain soy protein isolates

You will be given 14 soy samples on a tray. Please make sure to use throughout the test.
Rate on a 1-9 liking and note flavor characteristics

Soy sample code	Protein (%)	Manufacturer Code	Hedonic Liking	Characteristics
20501	90	99301		
20502	53	99302		
20503	90	99302		
20504	90	99303		
20505	90	99301		
20506	100	99301		
20507	69	99301		
20508	80	99304		
20509	70	99304		
20510	69	99302		
20511	69	99302		
20512	69	99302		
20513	80	99303		
20514	60	99303		

SCORE SHEET (B)

Product Formulation and Sensory Acceptance of Three Soy Concept Foods Utilizing Three Different Soy Derivatives

Product: Cranberry Nut Soy Pudding

Two Bean Soy Dip

Soy Based Meal Replacer

Please taste each sample. Rinse between samples with the water provided. Then rate each sample as follows: Each column should have only one check mark

862	756	544	Texture
			Like Extremely
			Like very much
			Like moderately
			Like slightly
			Neither like nor dislike
			Dislike slightly
			Dislike moderately
			Dislike very much
			Dislike extremely

862	756	544	Flavor
			Like Extremely
			Like very much
			Like moderately
			Like slightly
			Neither like nor dislike
			Dislike slightly
			Dislike moderately
			Dislike very much
			Dislike extremely

862	756	544	Appearance
			Like Extremely
			Like very much
			Like moderately
			Like slightly
			Neither like nor dislike
			Dislike slightly
			Dislike moderately
			Dislike very much
			Dislike extremely

862	756	544	Overall Liking
			Like Extremely
			Like very much
			Like moderately
			Like slightly
			Neither like nor dislike
			Dislike slightly
			Dislike moderately
			Dislike very much
			Dislike extremely

Thank You for your participation!!!

Comments: ____

CONSENT FORM

(You Must Be 18 Years Old to Participate)

Title of Study: Product Formulation and Sensory Acceptance of Three Soy Concept Foods Utilizing Three Different Soy Derivatives

Product: Soy Concept Foods

Study Site: Garrison Sensory Evaluation Laboratory and/or Mississippi State University Campuses, Off-Site Facilities and Locations

Name of Researcher(s) & University affiliation:

- **Aditya Samala,** Mississippi State University, Graduate Student
- **Dr. Patti C. Coggins**, Director, Garrison Sensory Lab, Mississippi State University

What is the purpose of this research project? The purpose is to determine the consumer acceptability of a Soy Concept Food.

How will the research be conducted? You will be given samples of product to taste, compare, and will be asked to fill out a questionnaire.

Are there any risks or discomforts to me because of my participation? No

Does participation in this research provide any benefits to others or me? Yes. Results of this study may provide the consumer with a new type food choice and will benefit soy producers by increasing demand.

Will this information be kept confidential? Yes

Who do I contact with research questions? If you should have any questions about this research project, please feel free to contact **Dr. Patti C. Coggins**, 662-325-4002. For additional information regarding your rights as a research subject, please feel free to contact the MSU Regulatory Compliance Office at 662-325-3294.

****If the study is physical in nature or is considered by the IRB to be more than minimal risk the following question must be included:**
What do I do if I am injured as a result of this research?
In addition to reporting an injury to **Dr. Patti C. Coggins**, 662-325-4002 and to the Regulatory Compliance Office (662-325-3294), you may be able to obtain limited compensation from the State of Mississippi if the injury was caused by the negligent act of a state employee where the damage is a result of an act for which payment may be made under §11-46-1, et seq. Mississippi Code Annotated 1972. To obtain a claim form, contact the University Police Department at *MSU UNIVERSITY POLICE DEPARTMENT, Butler-Williams Bldg, Mississippi State, MS 39762, (662) 325-2121*.

What if I do not want to participate?
Please understand that your participation is voluntary, your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and you may discontinue your participation at any time without penalty or loss of benefits.

You will be offered a copy of this form for your records.

______________________________ ____________
Participant Signature Date

______________________________ ____________
Investigator Signature Date